Wheelchair half-marathon and marathon performance – the 'Oita International Wheelchair Marathon' 1983-2011

Knechtle, B ; Lepers, R

Abstract: We compared participation and performance trends of individuals with disabilities competing in the half- and full-marathon in the 'Oita International Wheelchair Marathon' from 1981 to 2011. The performance times decreased during the 1980's until the middle 1990's and stabilized thereafter for both half-marathoners and marathoners. The mean top five overall finishers times were 0:52±0:07 h:min for half-marathoners and 1:36 ±0:11 h:min for marathoners, respectively. The mean age of the finishers increased significantly ($p < 0.01$) by 0.51 year per annum for the half-marathoners and by 0.62 year per annum for the marathoners, respectively. There was a significant ($p < 0.001$) age effect on time performance for both distances. The best time performance was observed for the age comprised between 16 and 54 years for half-marathoners, and between 25 and 49 years for marathoners, respectively.

DOI: https://doi.org/10.4100/jhse.2013.84.08

Original Article

Wheelchair half-marathon and marathon performance – the 'Oita International Wheelchair Marathon' 1983-2011

BEAT KNECHTLE[1], ROMUALD LEPERS[2]

[1] *Gesundheitszentrum St. Gallen, St. Gallen, Switzerland*

[2] *Faculty of Sport Sciences, University of Burgundy, Dijon, France*

ABSTRACT

Knechtle, B. & Lepers, R. (2013). Wheelchair half-marathon and marathon performance – the 'Oita International Wheelchair Marathon' 1983-2011. *J. Hum. Sport Exerc., 8*(4), pp.974-985. We compared participation and performance trends of individuals with disabilities competing in the half- and full-marathon in the 'Oita International Wheelchair Marathon' from 1981 to 2011. The performance times decreased during the 1980's until the middle 1990's and stabilized thereafter for both half-marathoners and marathoners. The mean top five overall finishers times were 0:52±0:07 h:min for half-marathoners and 1:36 ±0:11 h:min for marathoners, respectively. The mean age of the finishers increased significantly ($p < 0.01$) by 0.51 year per annum for the half-marathoners and by 0.62 year per annum for the marathoners, respectively. There was a significant ($p < 0.001$) age effect on time performance for both distances. The best time performance was observed for the age comprised between 16 and 54 years for half-marathoners, and between 25 and 49 years for marathoners, respectively. **Key words**: ENDURANCE, AGING ATHLETES, INDIVIDUALS WITH DISABILITY, SPINAL CORD INJURY

Corresponding author: Facharzt FMH für Allgemeinmedizin Gesundheitszentrum St. Gallen Vadianstrasse 26 9001 St. Gallen, Switzerland.
E-mail: beat.knechtle@hispeed.ch
Submitted for publication May 2013
Accepted for publication November 2013
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202

doi:10.4100/jhse.2013.84.08

INTRODUCTION

Marathon running is of high popularity (Burfoot, 2007). Hundreds of marathon races are offered worldwide and hundreds of thousands of runners compete each year in marathon races (Burfoot, 2007; Jokl et al., 2004; Lepers & Cattagni 2012; Leyk, et al., 2007; Leyk et al., 2009). The performance in marathon running is still improving in elite runners. From 1969 to 2010, the mean time differences were 3 min 20 sec ± 1 min 59 sec and 7 min 1 sec ± 2 min 48 sec, corresponding to an improvement of 5 and 10 sec per annum for leading times and top 200 times, respectively (La Torre et al., 2011).

Apart from marathon running in able-bodied athletes, wheelchair marathon races do exist for individuals with disability (Cooper, 1990; Ogata, 1994). In earlier times, wheelchair sports were used as a method of rehabilitation to increase the recreational activity of individuals with disability (Cooper, 1990). In recent times, however, wheelchair sports have been expanded to include competitions for wheelchair athletes. There are numerous international wheelchair competitions and races all over the world (Ogata, 1994) where wheelchair races are also held at the Paralympics (Cooper, 1990; Gold & Gold 2007).

Participation and performance trends for able-bodied half and full marathoners over the last three decades have been previously described (Jokl et al., 2004; Lepers & Cattagni, 2012; Leyk et al., 2007), but not for wheelchair cyclists competing in half- and full-marathons. In 1975, the first paraplegic completed in the 'Boston Athletic Association Marathon' a marathon in a wheelchair (Cooper, 1990). Since then, wheelchair cyclists can compete in famous city marathons such as the 'New York City Marathon' (www.nycmarathon.org) or the 'Boston Marathon' (www.baa.org) in a specific wheelchair category. Apart from these city marathons, a race exclusively for wheelchair cyclists is offered in Oita, Japan. The 'Oita Wheelchair Marathon Race' (www.wheelchair-marathon.com) is one of the most traditional wheelchair marathon races held worldwide. The race has been held since 1981 as a half-marathon and since 1983 also as a marathon. In the 'Oita Wheelchair Marathon Race', several investigations related to aspects of immunology (Furusawa et al., 2007), energy metabolism (Asayama et al., 1984), kinetic factors of wheelchair propulsion (Okawa, et al., 1999), and physical fitness (Asayama et al., 1985) have been performed. However to date, no study has described the participation and performance trends in this event.

In elite able-bodied marathoners, the age of peak performance appears similar for both females and males at around 30 years (Hunter et al., 2011). The time to complete a marathon gradually increases with age, with substantial losses in performance after the age of 70 years (Trappe, 2007). However, for recreational marathoners, there are no relevant running time differences in marathon finishers aged from 20 to 55 years (Leyk et al., 2009). Similar finding has been evidenced for half-marathoners where identical race times were observed for recreational runners aged between 20 and 49 years (Leyk et al., 2007). In contrast to able-bodied athletes, the age to peak performance in endurance wheelchair racing such as half- and full marathon and the age-related decline half- and full marathon have not been investigated in individuals with disability.

In this context, the aims of this study were to investigate (i) the participation trends in both wheelchair half-marathoners and marathoners at the 'Oita Wheelchair Marathon Race' from 1981 to 2011, (ii) the change in the age of the top five and overall finishers across the years and (iii) the age-related change in wheelchair half-marathon and marathon performance. Based upon results of able-bodied half-marathoners and marathoners, we hypothesized that (i) participation in both marathon and half-marathon wheelchair cyclists would increase across years, (ii) the mean age of the finishers would increase across years and (iii) the age related decline in performance would be more pronounced for marathoners than for half-marathoners.

MATERIAL AND METHODS

In the present paper, we focus our attention on the half-marathon and marathon races in 'Oita Wheelchair Marathon Race', because these events are ones of the oldest in the field of wheelchair road racing in the world and these races are exclusively reserved to wheelchair athletes. Approval for this study was obtained from the Institutional Review Board. It involved the analysis of publicly available data so content was waived. Name, age and time performance data for all wheelchair athletes completing the Oita (Japan) international wheelchair half-marathon (21.1 km) and marathon (42.2 km) from 1981 to 2011 were obtained through the 'Oita Wheelchair Marathon Race' web site (www.wheelchair-marathon.com). The first Oita wheelchair half-marathon was held in 1981 while the first full marathon was held two years later in 1983.

Procedures

Because of the small participation of female wheelchair athletes with less than 10% on both events, we considered only male wheelchair athletes independently of their disability classification. The level of the lesion of the spinal cord following American Spinal Injury Association (ASIA) was not considered. We focused on the results from the overall ranking without respect to the classification of the International Stoke Mandeville Wheelchair Sports Federation (ISMWSF). Only in 2004, the race organizer started to rank the athletes competing in the T34/53/54, T33/52, and T51 classes for males. Therefore, the classification was not available from the beginning of the race. The age of the athletes was only available since 2003. To focus on changes in participation and performance in male wheelchair athletes across the age, we distinguished the age groups as follows: 16-24 years, 25-29 years, 30-34 years, 35-39 years, 40-44 years, 45-49 years, 50-54 years, 55-59 years, 60-64 years, 65-69 years, 70-74 years, and 75 years and older. In order to analyse the age-related change in half-marathon and marathon performances, we pooled data from 2003 to 2011. We therefore considered the performances of the top ten wheelchair athletes per age group for each distance during the 9-year period. Because of the the small participation of athletes in the age group 75 years and older in half-marathon and athletes in the age groups 70-74 and 75 years and older in marathon, we did not consider these age groups in the analysis of the age-related change in performance.

Statistical Analyses

Data are reported as means±SD in the text. Linear regressions were used for estimating the changes of the mean age of participants across the years. Pearson's correlation coefficients were used to assess the association between various variables (Statsoft, Version 6.1, Statistica, Tulsa, OK, USA). One-way ANOVA was used to compare the race times between the different age groups for both half-marathon and marathon. Tukey's post hoc analyses were used to test differences within the ANOVA when appropriate. Statistical significance was accepted at $p < 0.05$.

RESULTS

From 1981 to 2011, there were 4,747 male finishers in the half-marathon and from 1983 to 2011, 3,566 male finishers in the marathon, respectively. The number of finishers each year over the history for both events is shown in Figure 1. For both races, there was an increase of finishers until the beginning of 1990's and then a progressive decrease. The average number of finishers per year was 153±45 in the half-marathon and 123±43 in the marathon, respectively.

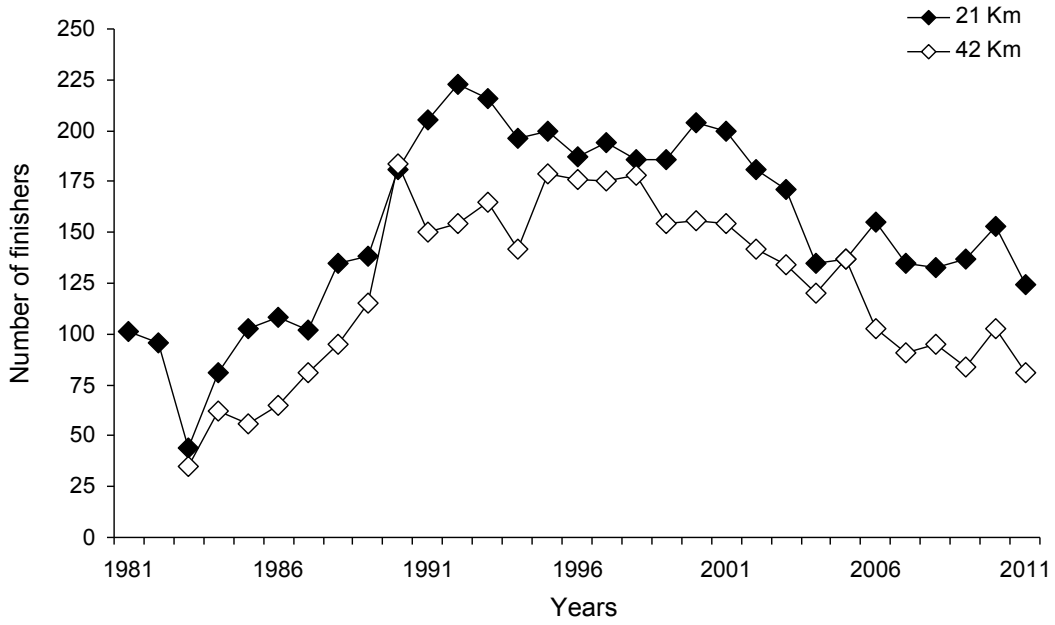
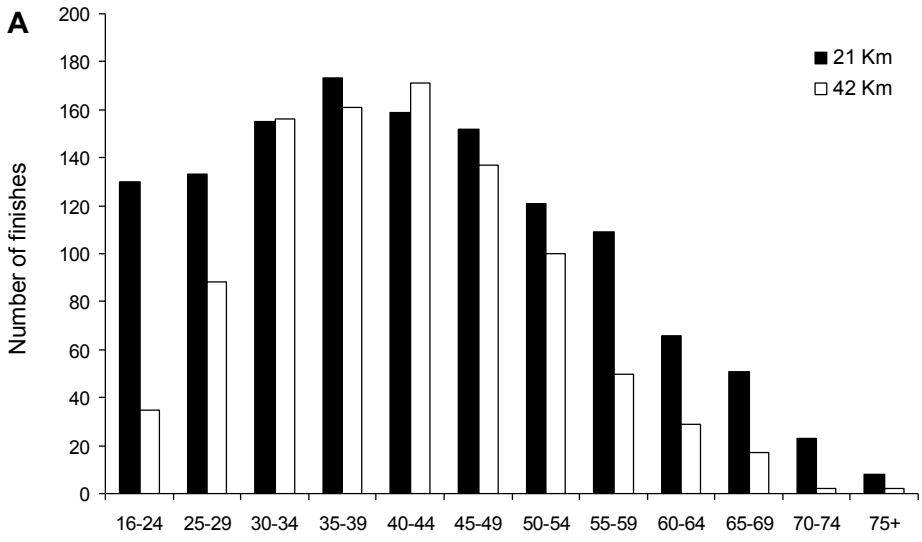


Figure 1. *Number of male finishers at the 'Oita Wheelchair Marathon Race' half-marathon (21.1 km) and marathon (42.2 km) from 1981 to 2011. The first Oita marathon was held in 1983.*

The age distribution of both half-marathon and marathon finishers during the 2003-2011 period is shown in Figure 2. The 5-year age bracket with the absolute largest participation during this period was 35-39 years for half-marathon and 40-44 years for marathon, respectively (Figure 2, Panel A). The relative distribution of ages showed that the participation of wheelchair marathoners was more concentrated between 30 and 50 years old compared to half-marathoners, for which participation was more distributed across the age groups (Figure 2, Panel B).



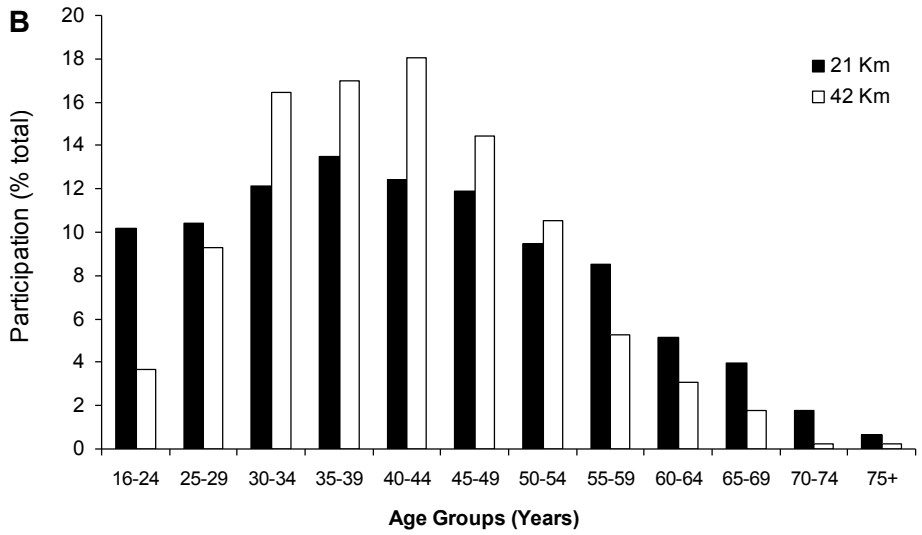
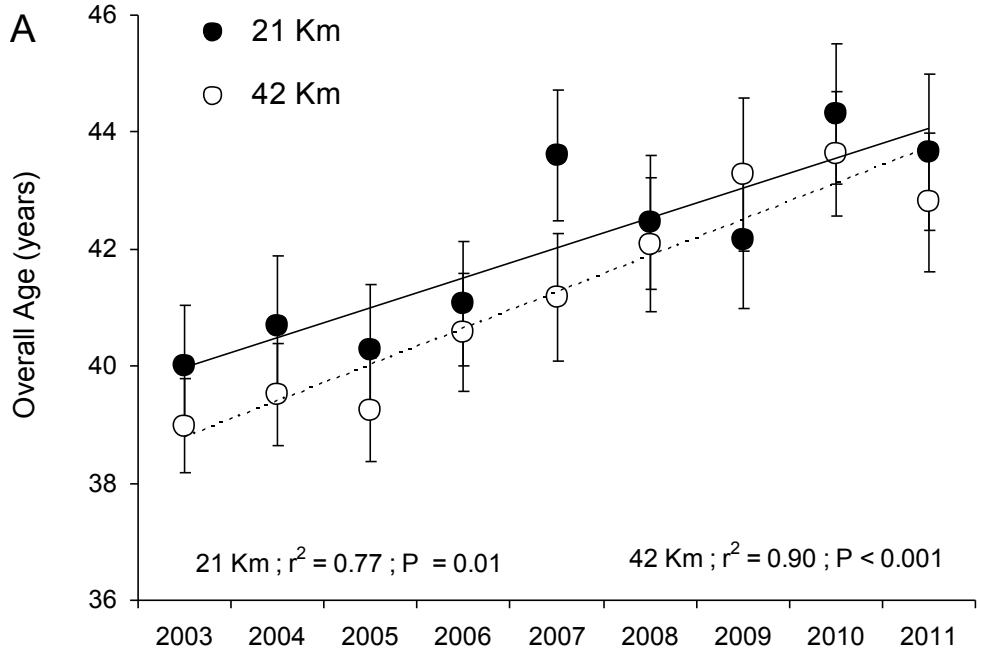


Figure 2. *Number of finishers per age group (Panel A) and percentage of finishers per age group (Panel B) at the 'Oita Wheelchair Marathon Race' half-marathon (21.1 km) and marathon (42.2 km) from 2003 to 2011*

Figure 3 shows the historical age trends of overall finishers and top five overall finishers for both half-marathon and marathon between 2003 and 2011. During the period studied, the mean age of the finishers increased significantly by 0.51 year per annum for the half-marathoners and by 0.62 year per annum for the marathoners, respectively (Figure 3 Panel A). From 2003 to 2011, the mean age of the top five overall finishers did not significantly change across the years (Figure 3 Panel B). The mean age of the top five athletes was equal to 34.4±4.2 years for the half-marathoners and 34.9±2.3 years for the marathoners, respectively.



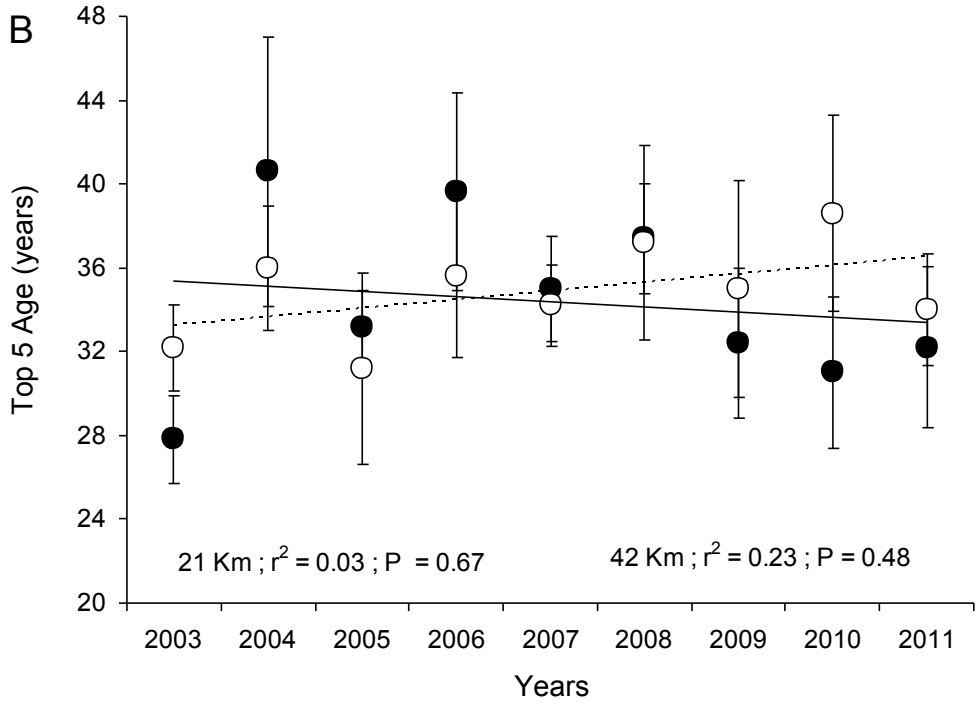


Figure 3. *Mean (±SE) age of the male overall finishers (Panel A) and top five overall finishers (Panel B) at the 'Oita Wheelchair Marathon Race' half-marathon (21.1 km) and marathon (42.2 km) from 2003 to 2011. The dotted lines and solid lines represent the linear regressions for the marathon and half-marathon, respectively*

The historical time performance trends of the top five male overall (Panel A) and overall finishers (Panel B) is shown for both half-marathon and marathon in Figure 4. During the 1981-2011 period, the top five time performances decreased during 1980's until the middle 1990's and stabilized thereafter for both half-marathon and marathon. The mean top five times were 0:52±0:07 h:min [range: 0:45 - 1:14 h:min] for half-marathoners and 1:36±0:11 h:min [range: 1:23 - 2:10 h:min] for marathoners, respectively. The mean difference in time between the top five overall marathoners and half-marathoners was 44±5 min (i.e. 85±7%). The mean time of overall finishers followed the same trends than the top five overall finishers. During the studied periods, the mean overall times were 1:17±0:08 h:min [range: 1:08 - 1:41 h:min] for half-marathoners and 2:06±0:13 h:min [range: 1:52 - 2:41 h:min] for marathoners, respectively. The mean difference in time between the overall marathoners and half-marathoners was 50±4 min (i.e. 66±6%).

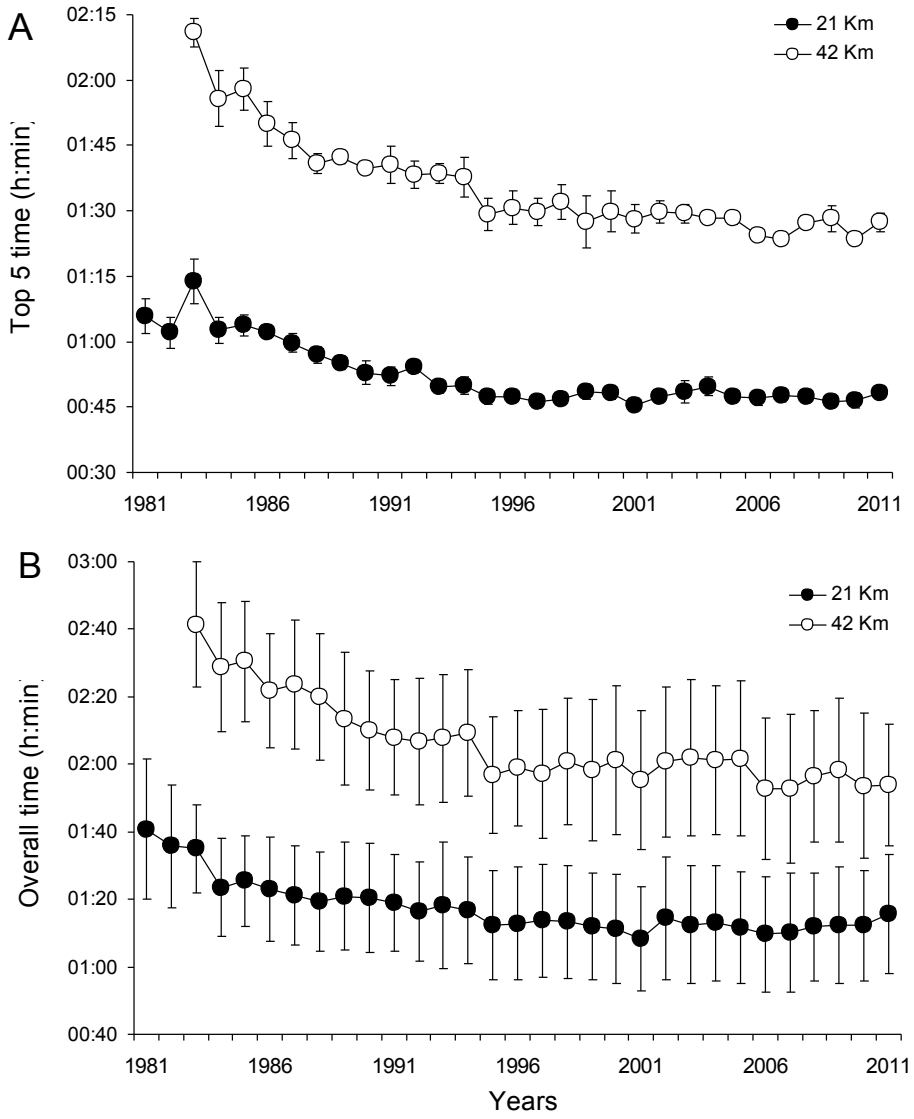


Figure 4. *Mean (±SD) performance times of the top five male overall (Panel A) and the male overall (Panel B) finishers at the 'Oita Wheelchair Marathon Race' half-marathon (21.1 km) and marathon (42.2 km) from 1981 to 2011*

The mean age-related changes in both half-marathon (Panel A) and marathon (Panel B) race times throughout 2003-2011 are shown in Figure 5. The race time increased in a curvilinear manner with advancing age for both races. There was a significant age effect for half-marathon ($F = 42.4$, $p < 0.0001$) and marathon ($F = 43.9$, $p < 0.0001$) race times. No significant difference in time was observed for the seven age groups between 16 to 24 years and 50 to 54 years for half-marathon, and for the four age groups between 25 to 29 years and 45 to 49 years for marathon. For half-marathon, the race time was significantly ($p < 0.01$) longer for the age groups 60 to 64 years and older compared with the age groups between 16 to 24 years and 55 to 59 years. For marathon, the race times were significantly ($p < 0.01$) longer for the age groups 50 to 54 years and older compared with the age groups between 25 to 29 years and 35 to 39 years.

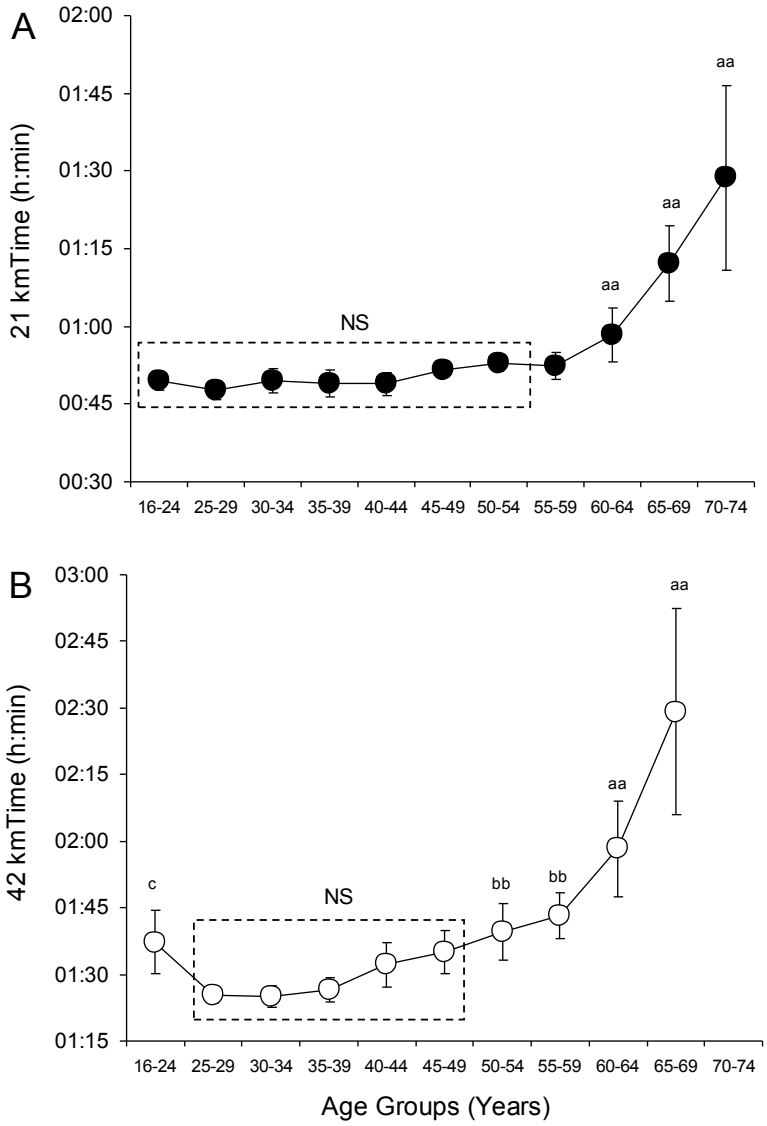


Figure 5. *Age-related changes in performance at the 'Oita Wheelchair Marathon Race' half-marathon (21 Km, Panel A) and marathon (42 Km, Panel B) from 2003 to 2011. Values are means ± SD. For half-marathon, race time was not significantly different (NS) for the age groups between 16-24 and 50-54 years. For marathon, race time was not significantly different (NS) for the age groups between 25-29 and 45-49 years.*

aa : Significantly different ($p < 0.01$) from all age groups between 16-24 and 55-59 years.
bb : Significantly different ($p < 0.01$) from all age groups between 25-29 and 35-39 years.
c : Significantly different ($p < 0.05$) from all age groups between 25-29 and 30-34 years.

DISCUSSION

In the present study, we intended to investigate the participation trends in both wheelchair half-marathoners and marathoners, the change in the age of the top five and overall finishers and the age-related change in wheelchair half-marathon and marathon performance.

The results showed that the participation in half-marathoners was greater compared to marathoners. After a peak in participation in the 1990s, the number of finishers progressively decreased for both distances. The race in Oita started in 1981 with a half-marathon and in 1983, a full marathon was also offered. Most probably, the half-marathon distance is still more attractive in wheelchair half-marathoners although for able-bodied athletes, marathon running seems to be more popular than half-marathon running (Leyk et al., 2007; Leyk et al., 2009). Regarding the participation in age groups, the highest participation was found in the age group 35-39 years for half-marathoners and in the age group 40-44 years for marathoners. Since participation was higher in half-marathoners compared to marathoners and half-marathoners compete at younger ages than marathoners, we suppose that wheelchair athletes start to compete in half-marathon and will change later to the marathon distance. The decrease in participation in marathoners is in contrast with previous findings on able-bodied marathoners. In popular city marathons like the 'New York City Marathon', participation increased in the last decades (Lepers & Cattagni, 2012). An explanation for the decrease in wheelchair marathon racing could be a higher participation in other wheelchair sports such as wheelchair basketball (Kokaridas, et al., 2010). While training and racing in a wheelchair marathon is rather individual, athletes playing basketball in a team have more social interactions which may help to better handle the situation of disability (Giacobbi et al., 2008).

For both wheelchair half-marathoners and marathoners, performance improved in the 1980's and 1990's, but stabilized since the end of 1990's. The main reasons to explain the decrease in race time are the improvement in material (Coutts, 1991; Kauzlarich & Thacker, 1985; Liu et al., 2008; Liu et al., 2010) and training (Bernardi et al., 2010; Okuma et al., 1989). Intense physical training via wheelchair propulsion can markedly enhance upper body cardiovascular fitness in paraplegics (Hooker & Wells, 1992) and individual training for wheelchair marathoners improves the competitors' physical fitness over several years (Okuma et al., 1989). Athletes with spinal cord injury can maintain their fitness for 20 years when they maintain their sports activities (Shiba et al., 2010).

An interesting finding was that the mean age of the finishers increased across the years. In the half-marathoners, the mean age of finishers was ~40 years in 2003 an increased to ~44 years in 2011, while for the marathoners, it was ~39 years in 2003 and increased to ~43 years in 2011. Although half-marathoners can achieve the same level performance for a greater age interval (i.e. 16 to 54 years) compared to marathoners (i.e. 25-49 years), the mean age of the top five overall finishers was similar for both half-marathoners and marathoners. For the top five athletes, the age of peak performance was unchanged at ~35 years for both half-marathoners and marathoners. A mean age of peak performance of ~35 years in endurance performance is in line with data from able bodied endurance athletes such as runners or triathletes (Lepers & Maffiuletti, 2011). However, the age of the top athletes in wheelchair marathon is higher compared to the age of top athletes in marathon running where the best male marathoner are at ~29 years of age (Hunter et al., 2011). An explanation could be that wheelchair athletes with a traumatic lesion of the spinal cord need time to recover after the trauma to start with training and racing.

The half-marathoners achieved the same level of performance between 16 and 54 years, while for the full marathoners, same level of performance change was observed between 25 and 49 years. These differences might be explained by physiological factors. Asayama et al. (1985) investigated physiological variables in athletes competing in both the marathon and the half-marathon in the 'Oita Wheelchair Marathon Race'; however the authors found no difference in physical fitness between the full and the half marathon elite finishers. Maximum oxygen uptake (VO2max) showed a fairly low value (35.0±3.8 ml/kg/min in the marathon versus 32.7±6.3 ml/kg/min in the half-marathon, respectively) in comparison with able-

bodied elite runners. However, the paraplegic participants had extremely high heart rates (171.6±20.5 beats/min versus168.1±9.8 beats/min, respectively) continuously throughout the race.

The half-marathoners were cycling faster compared to the marathoners and were able to achieve the same race time for a longer period of time in life. We assume that skeletal muscle mass is the link for these findings. The power of the upper arms and lung vital capacity played a major part in performance in wheelchair cyclists in the 'Oita Wheelchair Marathon Race' (Ide et al., 1994). Wheelchair athletes can only use the muscles of their upper body (i.e. arms, trunk) compared to able-bodied marathoners using their legs (Coutts et al., 1983). In paraplegic athletes, both the muscles of the shoulder girdles and the arms are markedly hypertrophic. On the contrary, leg muscles are extremely atrophic (Asayama et al., 1985). When wheelchair athletes were compared to able-bodied athletes, VO2max was considerably lower in wheelchair athletes compared to able-bodied athletes (Knechtle et al., 2003). However, endurance-trained wheelchair athletes are able to maintain velocities equivalent to the same relative exercise intensity for prolonged periods irrespective of their lesion level (Campbell et al., 2004). Wheelchair athletes can achieve a fast speed in a marathon due to high speeds attainable during downhill wheeling (Coutts & Schutz, 1988).

Limitations and implications for future research

In this data analysis, the level of the lesion of the spinal cord following ASIA was not considered. We focused on the results from the overall ranking without respect to the classification of ISMWSF. In 2004, the race organizer started to rank the athletes competing in the T34/53/54, T33/52, and T51 classes for males. Classification systems were introduced that a competition is fair for athletes of all levels of lesions. Athletes are divided into categories depending on their disability such as spinal cord injury or an amputee, or cerebral palsy. The classification guidelines are continually being changed to include more athletes. Future studies should investigate the participation and performance trends regarding the classification in the T34/53/54, T33/52, and T51 classes. Furthermore, we were not able to control of boosting (Bhambhani et al., 2010), which can enhance endurance performance in spinal cord injured athletes. Also, training was not recorded in these athletes. The kind of training and race preparation might have a considerable effect on race outcome (Karp, 2007).

CONCLUSIONS

The performance times at the Oita Marathon decreased during 1980's until the middle 1990's and stabilized thereafter for both half-marathoners and marathoners. During the studied period, the mean age of the finishers increased significantly for both half-marathoners and marathoners. The best time performance was observed for the age comprised between 16 and 54 years for half-marathon, and between 25 and 49 years for marathon, respectively. Future studies are needed to investigate the physiological characteristics of elite wheelchair endurance athletes and the reasons why wheelchair half-marathoners can maintained a high level of performance until older age than marathoners. The influence of the level of spinal cord lesion on wheelchair performance needs also investigating in additional studies.

REFERENCES

1. Asayama, K., Nakamura, Y., Ogata, H., Morita, H., Kodama, S. & Hatada, K. (1984). Energy expenditure of paraplegic marathon runners measured during a wheelchair marathon. *Journal of UOEH, 6(2),* pp.121-130
2. Asayama, K., Nakamura, Y., Ogata, H., Hatada, K., Okuma, H. & Deguchi, Y. (1985). Physical fitness of paraplegics in full wheelchair marathon racing. *Paraplegia, 23(5),* pp.277-287

3. Bernardi, M., Guerra, E., Di Giacinto, B., Di Cesare, A., Castellano, V. & Bhambhani, Y. (2010). Field evaluation of paralympic athletes in selected sports: implications for training. *Medicine and Science in Sports and Exercise, 42(6)*, pp.1200-1208
4. Bhambhani, Y., Mactavish, J., Warren, S., Thompson, W.R., Webborn, A., Bressan, E., De Mello, M.T., Tweedy, S., Malone, L., Frojd, K., Van De Vliet, P. & Vanlandewijck, Y. (2010). Boosting in athletes with high-level spinal cord injury: knowledge, incidence and attitudes of athletes in paralympic sport. *Disability and Rehabilitation, 32(26*), pp.2172-2190.
5. Burfoot, A. (2007). The history of the marathon: 1976-present. *Sports Medicine, 37(4-5)*, pp.284-287
6. Campbell, I.G., Williams, C. & Lakomy, H.K. (2004). Physiological and metabolic responses of wheelchair athletes in different racing classes to prolonged exercise. *Journal of Sports Sciences, 22(5),* pp.449-456.
7. Cooper, R.A. (1990). Wheelchair racing sports science: a review. *Journal of Rehabilitation Research and Development, 27(3),* pp.295-312
8. Coutts, K.D., Rhodes, E.C. & McKenzie, D.C. (1983). Maximal exercise responses of tetraplegics and paraplegics. *Journal of Applied Physiology, 55(2),* pp.479-482
9. Coutts, K.D. & Schutz, R.W. (1988). Analysis of wheelchair track performances. *Medicine and Science in Sports and Exercise, 20(2)*, pp.188-194
10. Coutts, K.D. (1991). Dynamic characteristics of a sport wheelchair. *Journal of Rehabilitation Research and Development, 28(3)*, pp.45-50
11. Furusawa, K., Tajima, F., Okawa, H., Takahashi, M. & Ogata, H. (2007). The incidence of post-race symptoms of upper respiratory tract infection in wheelchair marathon racers. *Spinal Cord, 45(7),* pp.513-517
12. Giacobbi, P.R. Jr., Stancil, M., Hardin, B. & Bryant, L. (2008). Physical activity and quality of life experienced by highly active individuals with physical disabilities. *Adapted Physical Activity Quarterly, 25(3),* pp.189-207
13. Gold, J.R. & Gold, M.M. (2007). Access for all: the rise of the Paralympic Games. The *Journal of the Royal Society for the Promotion of Health, 127(3)*, pp.133-141
14. Hooker, S.P. & Wells, C.L. (1992). Aerobic power of competitive paraplegic road racers. *Paraplegia, 30*, pp.428-436
15. Hunter, S.K., Stevens, A.A., Magennis, K., Skelton, K.W. & Fauth, M. (2011). Is there a sex difference in the age of elite marathon runners*? Medicine and Science in Sports and Exercise, 43(4),* pp.656-664
16. Ide, M., Ogata, H., Kobayashi, M., Tajima, F. & Hatada, K. (1994). Anthropometric features of wheelchair marathon race competitors with spinal cord injuries. *Paraplegia, 32*, pp.174-179
17. Jokl, P., Sethi, P.M. & Cooper, A.J. (2004). Master's performance in the New York City Marathon 1983-1999. *British Journal of Sports Medicine, 38*, pp.408-412
18. Karp, J.R. (2007). Training characteristics of qualifiers for the U.S. Olympic Marathon Trials. *International Journal of Sports Physiology and Performance, 2*, pp.72-92
19. Kauzlarich, J.J. & Thacker, J.G. (1985). Wheelchair tire rolling resistance and fatigue. *Journal of Rehabilitation Research and Development, 22(3),* pp.25-41
20. Knechtle, B., Müller, G., Willmann, F., Eser, P. & Knecht, H. (2003). Comparison of fat oxidation in arm cranking in spinal cord-injured people versus ergometry in cyclists. *European Journal of Applied Physiology, 90(5-6),* pp.614-619
21. Kokaridas, D., Perkos, S., Harbalis, T. & Koltsidas, E. (2009). Sport orientation and athletic identity of Greek wheelchair basketball players. *Perceptual and Motor Skills, 109(3),* pp.887-898

22. La Torre, A., Vernillo, G., Agnello, L., Berardelli, C. & Rampinini, E. (2011). Is it time to consider a new performance classification for high-level male marathon runners? *Journal of Strength and Conditioning Research, 25(12)*, pp.3242-3247
23. Lepers, R. & Maffiuletti, N.A. (2011). Age and gender interactions in ultraendurance performance: insight from the triathlon. *Medicine and Science in Sports and Exercise, 43(1),* pp.134-139
24. Liu, H.Y., Cooper, R.A., Pearlman, J., Cooper, R. & Connor, S. (2008). Evaluation of titanium ultralight manual wheelchairs using ANSI/ RESNA standards. *Journal of Rehabilitation Research and Development, 45(9)*, pp.1251-1267
25. Liu, H.Y., Pearlman, J., Cooper, R., Hong, E.K., Wang, H., Salatin, B. & Cooper, R.A. (2010). Evaluation of aluminum ultralight rigid wheelchairs versus other ultralight wheelchairs using ANSI/RESNA standards. *Journal of Rehabilitation Research and Development, 47(5*), pp.441-455
26. Lepers, R. & Cattagni, T. (2012). Do older athletes reach limits in their performance during marathon running? *Age (Dordr), 34(3),* pp.773-81
27. Leyk, D., Erley, O., Ridder, D., Leurs, M., Rüther, T., Wunderlich, M., Sievert, A., Baum, K. & Essfeld, D. (2007). Age-related changes in marathon and half-marathon performances. *International Journal of Sports Medicine, 28(6),* pp.513-517
28. Leyk, D., Erley, O., Gorges, W., Ridder, D., Rüther, T., Wunderlich, M., Sievert, A., Essfeld, D., Piekarski, C. & Erren, T. (2009). Performance, training and lifestyle parameters of marathon runners aged 20-80 years: results of the PACE-study. *International Journal of Sports Medicine, 30(5),* pp.360-365
29. Ogata, H. (1994). A review of wheelchair marathon and tennis. *Journal of UOEH, 16(3),* pp.201-217.
30. Okawa, H., Tajima, F., Makino, K., Kawazu, T., Mizushima, T., Monji, K. & Ogata, H. (1999). Kinetic factors determining wheelchair propulsion in marathon racers with paraplegia. *Spinal Cord, 37(8),* pp.542-547
31. Okuma, H., Ogata, H. & Hatada, K. (1989). Transition of physical fitness in wheelchair marathon competitors over several years. *Paraplegia, 27(3),* pp.237-243
32. Shiba, S., Okawa, H., Uenishi, H., Koike, Y., Yamauchi, K., Asayama, K., Nakamura, T. & Tajima, F. (2010). Longitudinal changes in physical capacity over 20 years in athletes with spinal cord injury. *Archives of Physical Medicine and Rehabilitation, 91(8),* pp.1262-1266
33. Trappe, S. (2007). Marathon runners: how do they age? *Sports Medicine, 37(4-5),* pp.302-305

